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Experimental Archaeology and Formation Processes: New Experiments with Spatial Modeling

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Experimental Archaeology and Formation Processes: New Experiments with Spatial Modeling

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Abstract

Formation processes, or the ways that ancient sites are formed, are of central interest to archaeology. Experimental archaeology has been useful in connecting and correlating human behavior with patterns in the archaeological record and has proved to be a growing field within the discipline. This thesis outlines an experimental study that examines the dispersal patterns of modern pottery during breakage, which can be used to simulate the structure of ceramic sherd assemblages in archaeological contexts. The study demonstrates the utility of 3D modeling in these archaeological contexts and its assistance in understanding the assemblages in a three dimensional context. The results offer a preliminary framework for documenting and analyzing artifact breakage and the formation of archaeological sites.

Chapter One: Introduction

Archaeologists often try to understand the past through ethnographic studies examining current day populations or examining the formation or creation of the archaeological record. The study of formation process remains a critical inquiry for archaeologists as the trash and refuse we discover offers a unique insight into both behavioral actions and the natural process of decay. These processes can be difficult to interpret (let alone recognize); however, new approaches such as ethnographic observation (ethnoarchaeology) and experimental archaeology have been used to understand these complex formations.

This study focuses on the formation of ceramic assemblages in the archaeological record in an attempt to further understand the complex (or contrasting simplistic) human behaviors and actions of the past. How do we determine that ceramic sherds recovered in the archaeological record were broken in the location they were found? How can we as archaeologists figure out the human behavior or event behind the creation of what we find today, especially artifacts found in fragments? This line of questioning may appear trivial or simplistic at first glance, however these inquiries directly relate to how we as archaeologists understand the past and human behavior (e.g., Sand 2013).

Consider that along a path leading to a well of water there are fragmented pieces of pottery. Archaeologists claim that these vessels were broken along the path to the well purposefully or under a ceremonial action. These conclusions sparked my first line of questioning in archaeology as I struggled to understand how we as archaeologists could assign such an elaborate action to an archaeological feature. How were we able to ascertain

the manner in which these pots were broken? Why are accidental causes ruled out? Were there certain markers that indicated they were purposefully broken? Basically, how do archaeologists know that a vessel was broken for ritual or ceremonial purposes?

In this thesis, I will discuss the concepts of formation processes that create the archaeological record and illustrate how we can infer these processes understand past human behavioral actions through experimental archaeology. Furthermore, I advocate for a new analytical (as well as documentative) approach to assessing, investigating, and understanding archaeological assemblages and their relative formation process in the archaeological record. I emphasize the use of photogrammetry and the subsequent creation of 3D models concerning these assemblages (ceramic in nature) as we examine their relative formation processes through experimental archaeology.

In Chapter Two (Formation Processes and Archaeological Experimentation), I briefly discuss previous research concerning experimental archaeology, formation processes, and photogrammetry. These subjects will be discussed in regards to their overall use within the discipline and relevance to ceramic breakage. In Chapter Three (Modeling Pottery Breakage), I begin with an overview of the project methodology. This section will also highlight some of the documentation methods used throughout the experiment as well as outlining the creation of the 3D models used in this research.

In Chapter Four (Results & Discussion), the results of the experiments will be of critical focus as we consider the various efficiencies of the documentation techniques implemented throughout these experiments and their relative use within the research. Certain issues and limitations will also be discussed within this chapter concerning unforeseen hindrances within the experiments and results themselves. Finally in Chapter

Five (Conclusions) I will conclude with a brief summary of my overall findings while highlighting the advantages of experimental archaeology in the field as well as photogrammetry as a whole. Future steps will also be addressed in this section as I outline possible alterations and further questions pertaining to the breakage experiments.

Chapter Two: Formation Processes and Archaeological Experimentation

In this chapter, previous studies concerning experimental archaeology, formation processes, and photogrammetry are introduced. Each of these aspects are expanded upon and discussed with their relative usage in archaeological practice. Furthermore, some caveats concerning these topics are briefly discussed as well as their advantageous potential for expanding the study of archaeology.

Experimental Archaeology: A Brief History

According to Skibo (1992:18), experimental archaeology “is the fabrication of materials, behaviors, or both, in order to observe one or more processes involved in the production, use, discard, deterioration, or recovery of material culture.” Before the modern era (that is, since the 1940s) experimental archaeology was a relatively unrecognized practice within archaeology consisting of singular or solitary experiments and unpublished research. Experimental archaeology emerged in the post-war era. Of course, long before this modern era, experiments were conducted in archaeological and historical settings, however, due to their lack of documentation and scientific methods, they were unable to be classified as true “experimental archaeology” as we view it today.

One memorable experiment, conducted around 1860, involved a man testing the musical sound of a horn (recovered in the archaeological record in 1698) which had previously only produced a “dull roar” unable to be heard from great distances (Coles 1979). In an attempt to understand the instruments original use, if not to signal others from a distance, Dr. Robert Ball of Dublin experimented with the horn arguing it must have

been used for musical enjoyment. Through a subsequent amount of effort, he was able to produce a “deep bass note resembling that of a bull” by blowing the horn with all of his might (Coles 1979:14). Sadly, he burst a blood vessel and died a few days later. Still, his experimental efforts mark one of the first attempts at experimental archaeology recorded.

The overall development of the experimental aspect of archaeology can be traced back to Scandinavian archaeologists who arguably can be attributed to what modern experimental archaeology is today. One specific archaeologist is no one other than Hans-Ole Hansen of Denmark who, in 1956, began building and destroying replicas of Danish houses (Coles 1979). His methods and intentions, considered unorthodox at the time, took the archaeological world by storm as well as the public’s imaginations regarding the previously regarded limitations of the discipline. His experimental endeavors even lead to one of the first permanent experimental archaeological sites in the world, which will be discussed later.

Much of modern experimental archaeology builds on the exploration of new techniques and approaches to understanding people of the past that were explored by Behavioral Archaeology in the 1970s and onward (La Motta and Schiffer 2001). These studies aimed to model processes and human actions of the past and how they related to and formed the archaeological artifacts and sites. On the subject of pottery, much of the resulting work has focused on the replication of vessels or other experiments designed to test functional aspects (e.g., vessel strength, see Neupert 1994; Rice 2015, Skibo 1995).

These attempts established “the foundation for future studies [and] contributed to our understanding of how to design experiments and how to interpret archaeological ceramics” and other features in an experimental setting (Ferguson 2010:17). Despite the

incredible potential of this archaeological interpretive approach, the amount of experimental archaeology conducted within the discipline today has been waning. As Ferguson reminds us, “experiments in archaeology have for the most part been justifiably ignored because of (1) their lack of a strong theoretical base and a resulting lack of general applicability in testing archaeological hypotheses...and (2) their lack of rigor and attention to scientific experimental procedure in design, execution, recording, and analysis” (Ferguson 2010:2).

Archaeological experiments have established themselves as “relevant to archaeological inference through research designs that explicitly address existing theories based on previous research” (Ferguson 2010:3). This progressive form of archaeology is more accessible to student researchers as it does not require traveling, is relatively inexpensive, and does not require the destruction of archaeological materials through excavation. Furthermore, experimental archaeology has a pull factor or draw that lies in its ability to provide data and results which would otherwise be unavailable to archaeologists in the field.

In archaeology, experimental research is typically implemented by researchers in order to further understand a concept or test theories developed during a study. Unlike more traditional methods, which rely on the artifacts found in the field, experimental archaeology allows researchers to target specific questions relating to creation, destruction, and use in the past. This form of archaeological investigation has helped expand our understanding concerning actions of the past and their relation to what we discover in the archaeological record and offers the possibility of modeling formation processes. Archaeologists call on experimental archaeology to help improve understanding

concerning formation processes and creation methods through these experimental endeavors.

Archaeology can be subjective in its interpretive approach as it relies typically on theoretical statements about archaeological discoveries. In other words, we cannot watch scenes from the past as we attempt to interpret ancient societies. Experimental archaeology provides archaeologist the opportunity to support or advocate theories and hypotheses that have had minimal archaeological supporting evidence. Within this exploratory method, experimental archaeology often adheres to the scientific method, testing hypotheses and using analytical procedures. Unlike other aspects of archaeology, experimental archaeology allows the possibility of future replication, which would otherwise be impossible in the field as you can only excavate a site once. Indeed this type of archaeology can go farther as it can explain alternative possibilities in archaeological investigative techniques and questioning making it extremely advantageous to the discipline

Caveats

Experimental archaeology is just that: experimental. These experiments can never fully reproduce the past nor replicate past behaviors as they are conducted in lab settings rather than ancient sites (this is discussed in more depth in the following section). With this in mind, can the results of experimental archaeology truly say anything definitive about the behaviors of people long past? I submit that the answer is yes, however, there are some limitations. The experiment is experimental and therefore is simply a test of theories and proposed practices. It is in no way definitive of ancient behavior but instead an attempt

to understand possible behavioral patterns, cultural techniques, or the overall creation of the archaeological record.

To Control or Not Control, That is the Question

The design of the archaeological experiment is important, with two basic possibilities: controlled and uncontrolled (the latter representing a more “realistic” understanding of the variability of the real world). Between these two approaches to archaeological experimentation there is a gradual change in the overall “environment” of the experiment itself. This change is found in the extent to which certain variables are controlled. On one end of the spectrum we have the very controlled experiments in which all variables are accounted for and can be controlled in one sense or another. On the other end we have the more natural experiments reflecting the reality of the world by controlling substantially less variables. Within this spectrum of control also lies the relative complexity of each experiment. For example we have some studies that deal with relatively simple controls such as experimental tool replications. Meanwhile there are more complex controlled studies such as experiments trying to create archaeological features. So how does an archaeologist determine what “environment” to conduct their experiments within? To control or not control, that is the question. Fortunately this question can be solved relatively easily as the type of “environment” depends on what the researcher is examining and how they are examining it.

When deciding which approach should be used, a researcher must reflect back on their research and the overall question they are asking. As Ferguson states, controlled laboratory experiments are commonly conducted in an aim to identify “general principles

that explain or describe the relationship between a technological property or material item” and some human behavior (Ferguson 2010:23). In contrast, experiments conducted in the field or in a more natural environment are used to assess whether the relationship between objects and human behavior is relevant to the interpretation of archaeological sites.

Each spectrum of control also has its advantages and disadvantages. For example, experiments that are highly controlled tend to examine a very narrow range of variables, which is advantageous to the researcher and future research due to the replicable conditions experienced in this type of “environment”. However, these highly controlled experiments, after controlling variables to a certain extent, can become too “far removed from archaeological inference” (as they begin to conduct scenarios in unrealistic atmosphere or “environments”) leaving the researcher with inapplicable results unless they are related to other observations or experiments (Ferguson 2010:5).

When it comes to less controlled experiments or those conducted in a more natural “environment”, it is found that the lack of control over variables “more closely replicate[s] possible prehistoric situations” which is advantageous for the archaeologists as they are trying to accurately study past behavior (Ferguson 2010:4). However, this also creates some limitations when it comes to replicating an experiment, as the conditions within the “environment” were never controlled and therefore are never guaranteed to be the same if replicated. For every question asked there lies an appropriate method of experimentation that can be applied to the research, however, it remains the researchers responsibility to discover the appropriate approach.

In all research, whether controlled or not, the most difficult variable to account for is

always the human user or researcher themselves. For example, if an archaeologist conducts an experiment, they are able to “more closely control the process” of the experiment in order to attain the results that they desire (Ferguson 2010:5). However, as many have recognized, this conduction of experimentation creates a bias. The experimenter can be a “poor proxy” when attempting to understand people from the past due to many variables. People from the past come from a different time and culture and were “more skilled at making and using their material culture” (Ferguson 2010:5). Furthermore, people in the past had different overall goals when they were, for lack of a better term, “performing” the action being replicated. Since the overall goals of the two participants are different, the experiment may be hindered and its effectiveness and accuracy may be called into question. Given all of these issues, how can identifiably credible results be derived from archaeological experiments? The answer is simple: have a plan. There are elements of research that are crucial to the overall success and credibility of a study. These steps are crucial and must not be overlooked when planning experimental research.

Effectiveness & Accuracy

Experimental research, like all research, must start with a hypothesis. Without a hypothesis the experiment can become a ship with no captain or steering wheel (and like all ships in this scenario, it will crash and sink). To avoid this, researchers should find something to explore or expand upon. All exploration derives itself from questions (after all, aren't all humans naturally curious?) Even just questioning how archaeologists know certain things about sites or objects can generate interesting research ideas. How do we know that this pot was dropped? Why do we know that it is ceremonial or ritual? What do

we identify that makes it such? Experimental archaeologists should challenge previous claims not for the sake of dismissing them, but in order to propel and expand research and archaeological techniques. The researcher also needs to understand the variables at play in the experiment as well as the forces behind these variables. Finally in order to truly grasp the differentiation between accidental and ceremonial actions, we must first understand formation processes or how the archaeological record is created.

Experimental Archaeology and Formation Processes

In archaeology, the formation processes refers to the manner in which artifacts are introduced into the archaeological record and are affected or altered until they are excavated. In other words, the focus is on how archaeological assemblages are created. Artifacts can be affected or altered in terms of their size, composition, and spatial distribution, to just name a few. In fact, there are many types of processes that are involved in this formation of the archaeological record such as “loss, abandonment, disposal of the dead, and caching behavior” (Schiffer 1987:47). Since these artifacts enter the archaeological record through some type of human behavioral action, archaeologists are extremely interested in understanding the dual nature of this formation process and past human behavior.

When it comes to pottery, archaeologists typically encounter complex assemblages of broken sherds. A reoccurring issue for ceramic archaeologists has been the “ ‘disjunction in units of observation’ (that is, whole pots versus sherds) and thus the fundamental problem is how pots break and enter the archaeological record” (Rice 2015:214). This fundamental problem was recognized and later addressed as archaeologists determined

the need for new principles of formation processes to be “established and applied in a thorough and systematic manner” (Schiffer 1987:8). This new systematic manner of study was found through emerging research strategies known as experimental archaeology and other forms of principles considered to be on the fringe of the discipline including, “ethnoarchaeology, historical archaeology, geoarchaeology, and vertebrate taphonomy” (Schiffer 1987:8). These strategies and new approaches attempted to study the formation or creation of the archaeological record, something which we still try to understand today.

So what does experimental archaeology tell us about the creation of the archaeological record? Experimental archaeology has provided the platform for creating modern simulations in which archaeologists are able to test their theories concerning human behavior and the formation of archaeological deposits (e.g., La Motta and Schiffer 2001; Neupert 1994). Formation processes have been experimented within larger and longer contexts at permanent sites such as Butser Ancient Farm and the Experimental Archaeological Center in Lejre, Denmark.

Since its initial conception in 1972, Butser Ancient Farm has been conducting a wide range of experimental archaeology from cultivation experiments examining the efficiency of tools and use ware patterns, to earthenware experiments examining the erosion of the soil and relative deterioration of artifacts. The farm’s nature is that of an open-air laboratory in which formation processes and overall archaeological studies can be conducted over a long span of time. Unlike other types of research, this farm allows archaeologists to cross-reference their theories and ideas against the complexities of the real world (Stone and Planel 1999).

In addition, the farm allows for archaeological experimentation concerning new

excavation and documentation techniques. This is especially relevant in this day and age given the advancing dependency and integration of computer technology into the field. The Butser farm serves as a past and current day example of the integration archaeological experimentation and emerging technologies. Like the world we live in today, this farm is always in the state of change as new experiments are conducted over time. Reynolds highlights the importance of exploring these formation processes through experimentation as he describes the farm as “a resource where hypotheses can be explored and where a negative answer is viewed as valuable as a positive answer” (Stone and Planel 1999:135).

In Denmark, another permanent site conducts experimental archaeology: the Archaeological Experimental Center at Lejre. The initial creation of this experimental center in 1967 resulted from an archaeological experiment conducted by scientists who wished to understand the destruction of Iron Age dwellings through fire. Although there was initial reluctance from the greater archaeological community, the center was created and the permanent study of experimental archaeology was established. From burning down houses to shooting various types of arrowheads from a bow, the center has continued to encourage archaeologists to explore their theories with experimental archaeology to this day (Stone and Planel 1999).

The center’s main goal still stands as it strives to “carry out research into the past through experimental archaeology” (Stone and Planel 1999:138). In Lejre, experimental archaeology is not seen as a method or tool to study the past with; instead it is seen as “a partner in the interpretation process” (Stone and Planel 1999:139). Like the Butser Farm, the center encourages experimental archaeology especially those that examine formation processes (such as the distribution of lithic waste) and technology both old and new.

Previous Experimental Research Involving Pottery

In an archaeological setting, “the degree of breakage [of an artifact] can yield parameters which can be of great value in interpreting a site,” however, there has not been a considerable amount of experimental archaeology focusing on this type of formation process (Orton 1993:32). Even fewer studies have been conducted specifically focusing on the spatial distribution and breakage of artifacts, namely ceramics. In addition to this, a relatively underwhelming amount of research has been conducted on “disturbance patterning” and its overall relation to breakage and spatial dispersal of artifacts. These disturbances are caused by human interaction or “burrowing animals like earthworms and gophers” which are viewed as “pesky creatures that gradually create turmoil in the spatial dimension [the soil]” (Schiffer 1987:18).

Despite the overall lack of research relating to these studies, the results of these few experiments have been fascinating and have contributed greatly to the overall understanding of formation processes involving ceramic breakage. For example, Blackham examined the “behavioral effects of the blind-mole rat and the effects of its behavior on archaeological deposits [ceramics]” in order to differentiate between human trampling and mole related damage to pottery (Blackham 2000:469). Originally thought to be purely animal instinct, these animals and their interaction with ceramic deposits and the stratigraphy of the soil had been ignored until this time. However, this study found that the burrowing activity of these mole rats were influenced and affected by the “degree and nature of human occupation” (Blackham 2000:473). In fact, “areas of intense human activity, or areas covered by buildings and features” were found to not be favored by these

animals due to its [the animal] main objective: “to reach a food supply of roots and bulbs just under the surface” (Blackham 2000:473). This type of disturbance, previously thought to be random activity has been shown to be more predictable through experimental archaeology while studying formation processes of archaeological sites.

Other experiments concerning the formation of archaeological sites have focused on more cultural events caused by humans such as trampling. Schiffer reminds us that “many cultural formations processes, from trampling to children playing in trash, are slow acting: undramatic in the short run, [and] are capable of inflicting substantial cumulative effects” pertaining to the archaeological record (Schiffer 1987:18). These cumulative effects have been studied through experimental archaeology in an attempt to understand the formation of the archaeological record in accordance with human interaction (e.g., Deal 1985; Gifford-Gonzales et al. 1985; La Motta and Schiffer 2001; Matthews 1965; Stockton 1973; Villa and Courtin 1983; Wilk and Schiffer 1979). In Wilk and Schiffer’s study concerning trampling it was observed that larger artifacts were moved or displaced away from paths and thereby not as crushed as other smaller artifacts (Wilk and Schiffer 1979). These discard processes or behaviors need to be research and experimented within, as the variability of these processes is too great to ignore (La Motta and Schiffer 2001).

There are few if any studies that approach the spatial dispersal of ceramic breakage in the ancient world through experimental archaeology. Due to the multiplicity of discard processes highlighted above, is it possible for archaeologists to determine the manner in which ceramics were discarded? Are there identifying markers in the breakage assemblages that are unique to certain scenarios or breakage actions? By using experimental archaeology, could archaeologists be able to differentiate accidental breakage

and purposeful or ritual breakage? And perhaps most important, how should experimental studies of breakage be documented and analyzed? What is the most effective methodology?

Of the broader concerns noted above, this project designed and conducted experiments with the aim to examine the relative special dispersal of pottery as it was broken from various heights. This decision to focus on accidental breakage stemmed from the inability to establish a consistent force on the pottery to ensure that all of the breakages would be comparable and identical (ensuring the replication of the experiments themselves). It was concluded that this could only be controlled through the use of a machine, which was not feasible at the time.

Although some experiments have been conducted focusing more traditional studies, archaeologists have been utilizing experimental archaeology to assess and examine new technologies being introduced today such as photogrammetry (e.g., Deal 1985). Indeed, photogrammetry is a new pathway for documenting archaeological scenes of interest as well as a new approach in analysis. Through the process of photogrammetry, three-dimensional models of archaeological scenes of interest can be further examined and analyzed.

A New Pathway for Experimental Archaeology: Photogrammetry (3D Models)

Since the first excavation, archaeology has dabbled with alternating types of documentary techniques in according with recording artifacts and relevant discoveries. This creation and eventual disillusionment of multiple techniques and technologies is nothing new to the discipline as once again it finds itself exploring a new documentary technique today. Photogrammetry is “the process of deriving measurements from

photographs through the use of trigonometry and overlaying photographs taken from various points of view” (Douglass et al. 2015:138). This process can be further utilized to create spatially realistic 3D models that can help analyze and understand an archaeological assemblage.

Previously, photogrammetry has been used in the archaeological field to capture entire sites or larger areas of excavation (e.g., Balsa-Barreiro and Fritsch 2018; Barsanti et al. 2013; Wernke et al. 2014). Recently, this technology has been adapted to document smaller arrays of objects. For example, in 2016, a team of archaeologists published their research involving photogrammetric analysis of individual anchors found off the coast of Cypriot. Without removing the anchors, the archaeologists were able to calculate the volume and mass of these objects by using photogrammetry (Fulton et al. 2016).

Photogrammetry has also been utilized in recording and documenting stone tool formation processes as shown in Matthew Magnani’s (2014) research on Middle Paleolithic stone cores. In this study, photogrammetric documentation and analysis proved to be successful in capturing ripple marks made from flake removals, showing not only the strike marks, but also the directionality of the strikes. Even museums have begun to utilize this technology to create online exhibits, collections, and records of objects (e.g., Barsanti and Guidi 2013; Seldon et al. 2014).

Photogrammetry has also been utilized in capturing and analyzing microscopic details present on objects of study (e.g., Alexander et al. 2015; Bourdier et al. 2015; Percoco et al. 2014, Percoco et al. 2017; Porter et al. 2016). For example, while examining rock art in caves throughout France, Russia, and Portugal, a group of archaeologists, through the use of photogrammetry, were able to analyze “millimetric and submillimetric details of

prehistoric petroglyphs and paintings” (Plisson 2015:102). In essence, photogrammetry is now used to analyze the spatial relationships of material culture at much smaller scales.

Photogrammetry serves as a powerful analytical tool as it allows for the examination of dispersal patterns while simultaneously preserving the details of the actual breakage scenario. Through this technology we are able to accurately examine and measure distances within this three-dimensional field of study without returning to the area of destruction, an attribute of this technique that I used in my own experimentation. By using this digital technology, it becomes possible to “analyze multiple scales of data and allow them [archaeology and Ecology] to reflect changes across each other’s spatial and temporal boundaries” (Evans and Daly 2006:131). Furthermore, this documentation technique can be utilized to create accurate 3D models that serve not only research aspects but preservation-oriented ones as well (e.g., Emmitt et al. 2017; Noya et al. 2015). The overall usage of photogrammetry in the field of archaeology is under recognized. Even further unrecognized is the potential photogrammetry and 3D models possess when analyzing archaeological assemblages. These techniques pair well with experimental archaeology as they can be further improved upon in the experimental realm of research. In the next chapter we shall discuss some methods of documentation utilized in these experiments as I attempt to examine the dispersal of pottery, as it is broken in a simulated “accidental” manner.

Chapter Three: Modeling Pottery Breakage

In this chapter the experimental set up is discussed along with the relative methodological approach taken while conducting these experiments. Documentation techniques utilized in capturing the results of these experiments are also discussed within this chapter and special emphasis is placed upon the use of photogrammetry and the creation of 3D models.

Methodology

The initial aim of this research was to examine the different dispersal patterns of ceramic pots in regards to the manner in which they were broken. More specifically, the experiments created and conducted were originally designed in an attempted to illuminate any patterns that would indicate if a vessel was broken accidentally or purposefully (the latter involving human force). When it came time to design these experiments, however, it became evident that there was no way to control the force exerted on the pots. As previously stated, this added force was a variable that needed to be controlled in order to examine the difference in dispersal patterns for accidental and purposeful breakage. This limitation led to the alteration of the overall research aim in which only gravitational or accidental breakage was studied. Given that gravity is always constant, and therefore a controlled variable, the experiments only altered the relative height drop. The variation in height altered the amount of force inflicted onto the pot when it impacted the ground: the greater the height, the greater the force applied to the pot.

Experimental Explanation & Set Up

This research was experimental, as modern day terracotta (planting) pots were broken instead of actual ancient vessels. Unlike ancient vessels, modern day terracotta pots are made by machines and nearly identical. Nonetheless, they were low-fired (under 1000 C) and approximate the technological processes of the majority of ancient pottery. These pots were broken on a concrete surface and it should be noted that this surface does not exactly match ancient floor material as was originally intended. Therefore, this research is not meant to be definitive nor an absolutely accurate breaking scenario of ancient times. Instead this research will be an experimental endeavor expanding upon studies concerning experimental archaeological techniques regarding ceramics. The real focus of the project, of course, is to outline new ways to apply photogrammetry to an experimental study of formation processes (in a lab setting).

Four different breaking scenarios were conducted throughout the course of this research: dropping nested (or stacked) pots at chest level, dropping a single pot at chest level, dropping nested pots at head level, and dropping a single pot at head level. These heights approximate the relative heights used in different transportation methods in the past concerning ceramic vessels. For example, one ethnographic study found that communities found in the Guatemalan highlands had three modes of carrying water jugs: balancing them on their heads, resting them on their hips, and carrying them on their backs (Reina and Hill 1978). Given the change in height between these carrying methods and the likelihood that one may trip while carrying them (resulting in the destruction of the vessel), these experiments were designed to focus on the variability of ceramic dispersal relative to the height they were dropped from. In order to gain a standard breaking scenario, each scenario was conducted twice. As previously stated, terracotta pots were utilized in this

experiment as they closely replicate the earthenware that typified ancient worlds (unslipped and fired at temperatures that are typically under 1000 degrees Celsius). These vessels were also low-cost, readily available substitutes to recreating ancient vessels and could easily be nested within one another as standardized forms.

These experiments were conducted over a grid system not unlike those constructed at an archaeological site when artifacts are recovered. Each breaking scenario conducted had the vessel (or vessels) striking the floor in roughly the same area of the grid. Initially, these pots were going to be broken on packed dirt in order to replicate ancient floors as much as possible; however, weather (more specifically snow) became an issue as these experiments were being conducted in Vermont. Ultimately, these experiments were conducted indoors on a painted cement surface. Ideal settings would better approximate the surfaces present in ancient landscapes.

Techniques Used

Before conducting the experiments, a camera was set up to record the initial breakage damage and dispersal patterns of each scenario. These trials were recorded in slow motion and used in the analysis of initial fragmentation of the vessels as they hit the ground. After each breakage scenario, data was recorded by photographing the scene using a Nikon D80 camera. The pictures were taken from at least two different heights (standing and kneeling) 360 degrees around the breakage scene. This allowed for the collection of data concerning the various positions of ceramic fragmentation and their relative dispersal. This would be instrumental later on as 3D models were created of the various scenes. Alongside these videos and photographs, the scenes were also sketched, identifying the

relative locations of each sherd and labeling them both in the sketch and on the sherd itself. The relative distance between various sherds was then measured to create a base line for the appropriate distance of dispersal. This, like the photographs, became instrumental later when creating the 3D models.

Personal Experimental Use of Photogrammetry

In order to avoid confusion concerning photogrammetry and the creation of 3D models, I first explain my experimental method process relating to photogrammetry in as much detail as possible in order to ensure future replication of these procedures (Fig. 1).

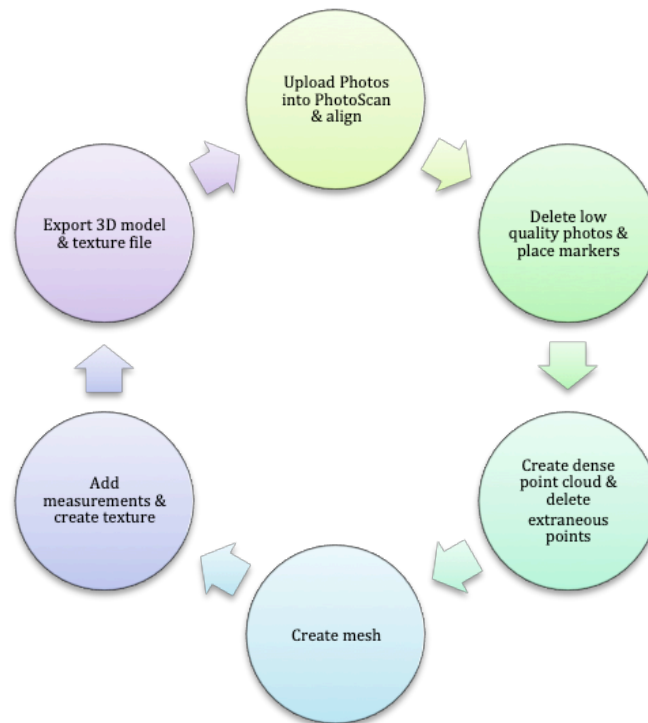


Figure 1. Chart of relative steps taken to create the 3D model.

Photographs of each breakage experiment were uploaded into Adobe PhotoScan software (version 1.4.3) and an image quality test was run. This test designated a number value to the photographs based on their overall clarity: .59 or lower being of bad or blurry

Markers or flags were then created and placed manually in each photograph in order to aid the computer later when it tried to find overlapping features in the photographs. These overlapping features identified by the markers are known as points. These markers were placed in the cross sections of the grid where black dots had been drawn before the experiments were conducted. The placement of these markers called for each photograph to be individually inspected and assigned locations of overlap (Fig. 3).

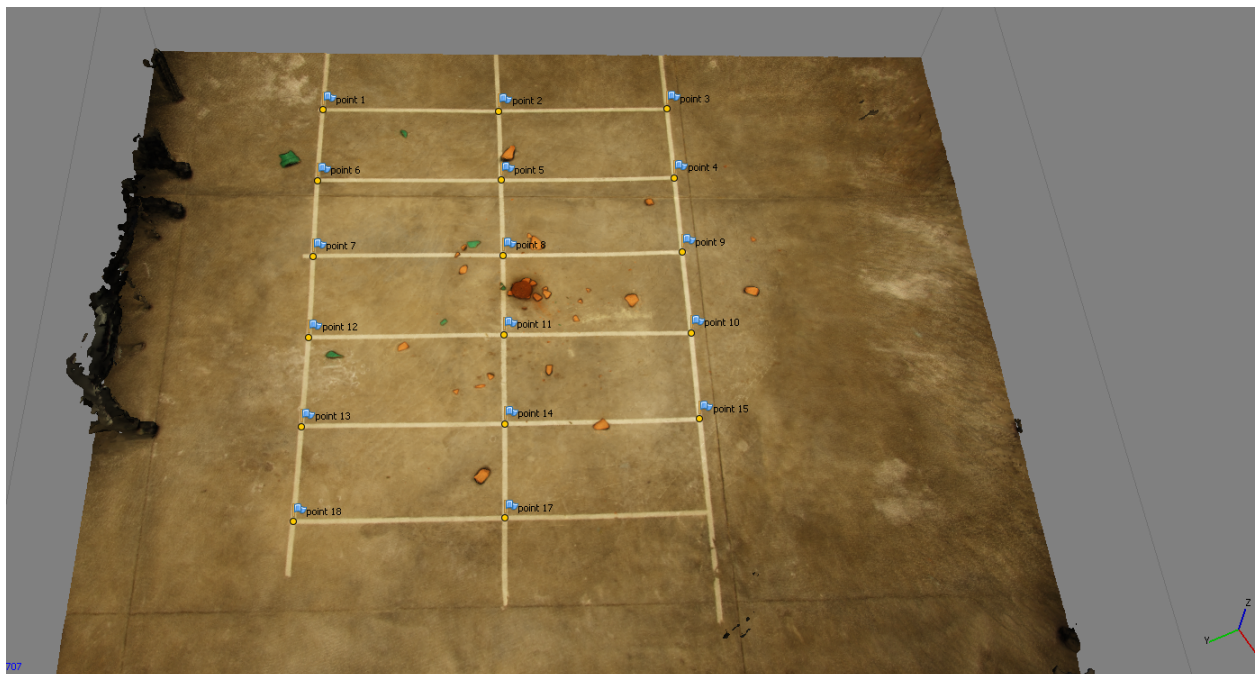


Figure 3. 3D model showing the markers, which were marked in the photographs and overlapped to create the model.

After the markers were placed in all the photographs, the computer set to work creating a dense point cloud (Fig. 4). This cloud was made up of the matching features present in all of the photographs thereby creating an abstract image of the scene. By the end of this processing step, the computer produced a cloud resembling the artistic style of “pointillism” in which the artist creates an image by creating small dots of color. If you look

at the image from a distance, it forms a picture; however, if you get closer you will notice the small circles of color that create the image. Like this style of art, the process can be quite long and, in this research, took between three to five days. This time frame depended upon the amount of photographs taken, the overall quality of the images, the number of markers placed, and the relative processing power of the computer.

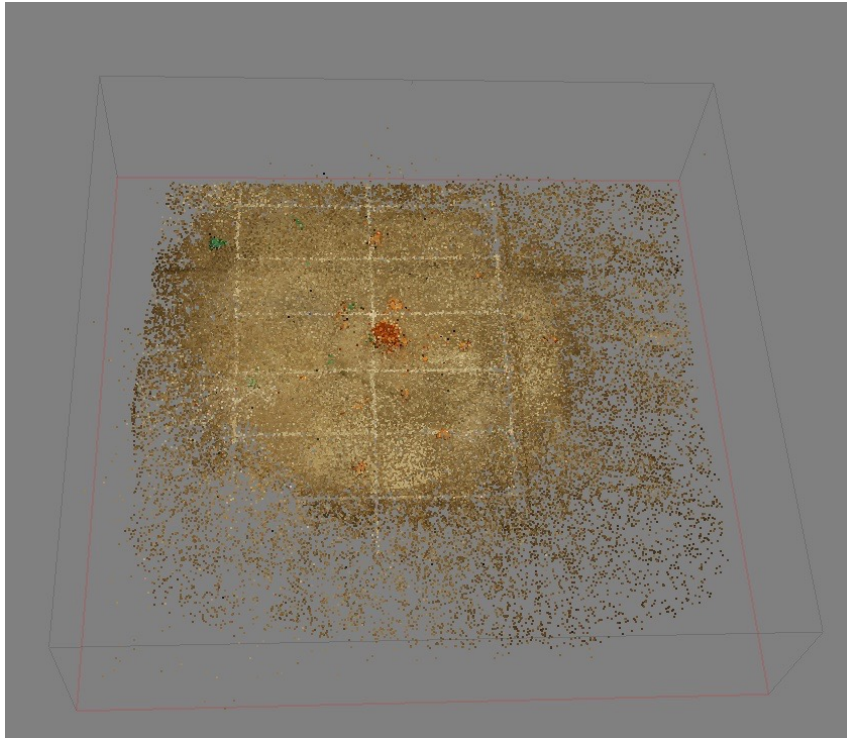


Figure 4. 3D model showing the creation of the dense point cloud.

With the dense point cloud created, extraneous points were manually deleted from the overall cloud-model. These extraneous points depicted elements such as backgrounds, walls, tables, and chairs, which had been matched across all of the photographs (Fig. 5). Finally, the computer created a mesh of the 3D model by filling in the missing areas in the point cloud where it had been unable to determine a correct color or matching feature in the photographs (Fig. 6). This process was relatively quick (thirty to forty-five minutes) given that the computer simply needed to estimate and extrapolate a relative colored point

based on surrounding points from the dense point cloud. The computer, after filling in these gaps, was able to create a basic frame or “mesh” of the breakage scene.

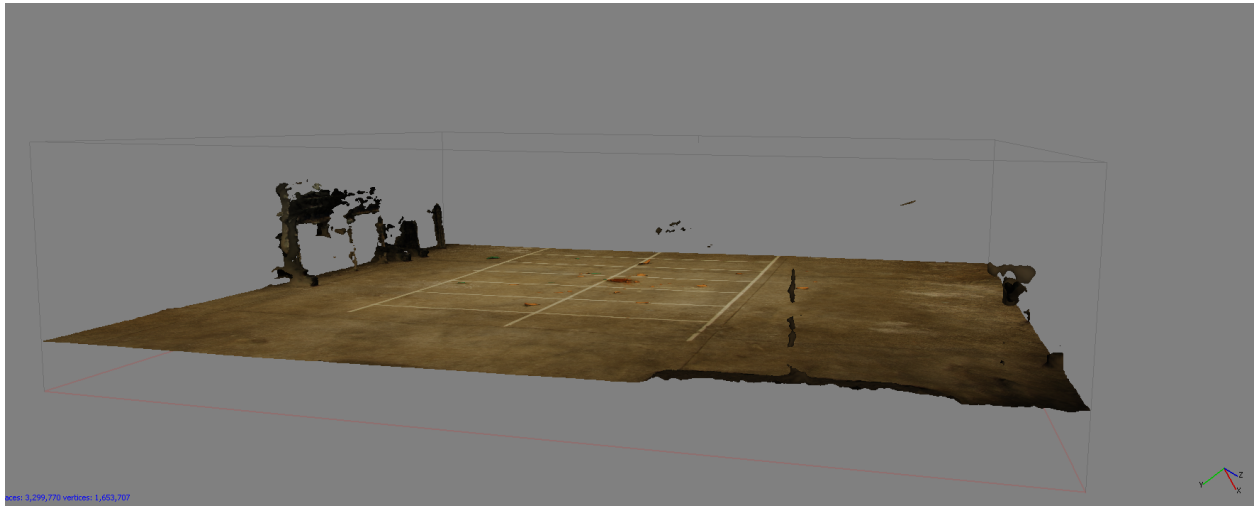


Figure 5. 3D model illustrating the extraneous points or objects captured in the initial dense cloud construction.



Figure 6. 3D model (left) showing the nearly complete model as the computer has filled in patches previously left blank or distorted with multiple shadowy images (right).

Measurements were then added to the nearly complete 3D model in order to correct any reality distortions created in the computer rendering process (Fig. 7). These measurements were taken from the systematic grid set up for the experiments and were measured before the experiments took place. When these measurements were added to the model, the spatial reality of the 3D model was tested as the computer calculated the

relative distance between two or more sherds within the program. The resulting distance between these fragments was then cross-referenced against measurements taken during the documentation of the scene.

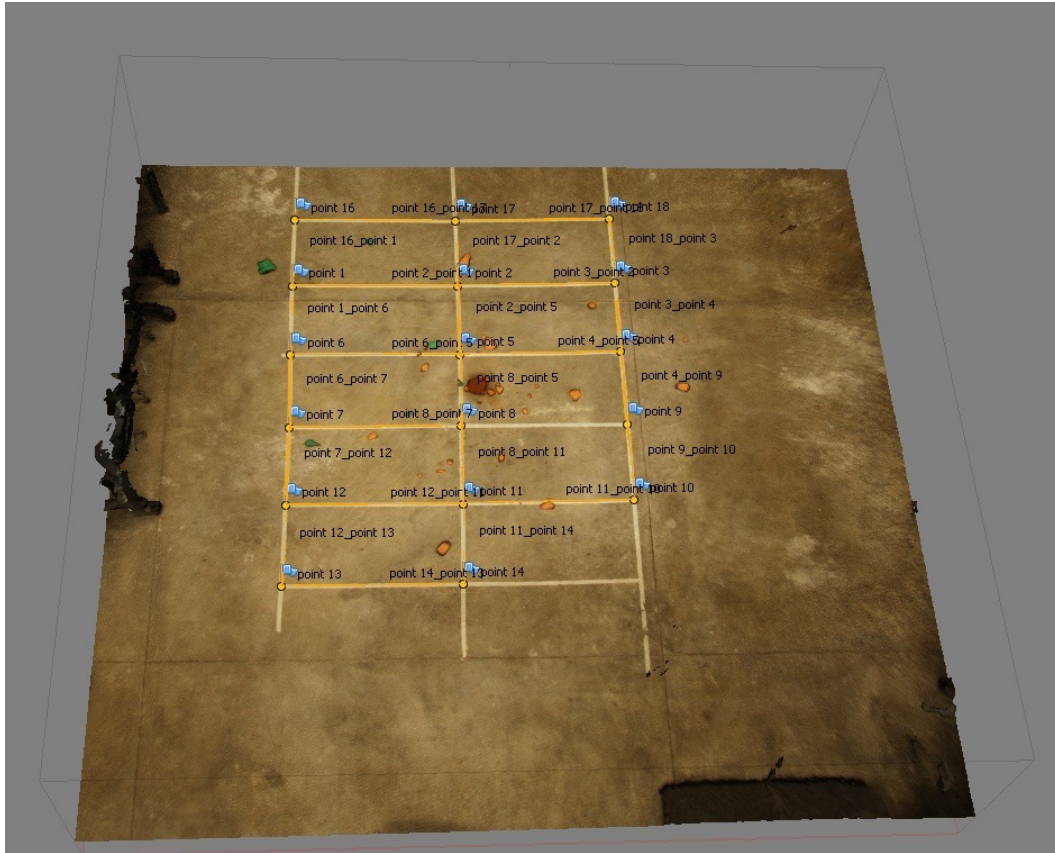


Figure 7. 3D model illustrating the measurements assigned to the model in order to correct any spatial distortion.

After confirming the accuracy of the three-dimensional space, a texture was then created as the computer used the set colors of the points that make up the point cloud (Fig. 9). This step shows no overall change in the 3D model when viewing it in Adobe PhotoScan as it is already present; however, this is a necessary step as it is crucial when exporting the 3D model since this texture file is saved apart from the model itself. If this step is not completed, any 3D model exported from the program will have no color or texture (Fig. 8).

In other words, it will appear as an outline or wire frame when opened again.

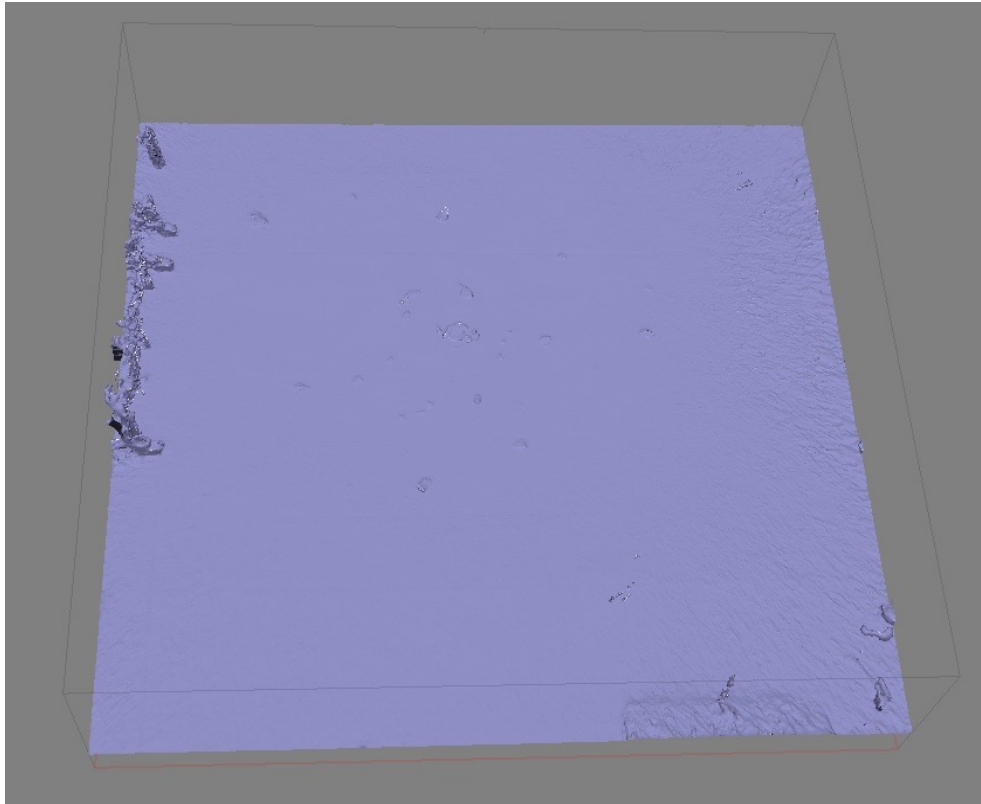


Figure 8. The failed result of a 3D model with no texture file attributed to it.

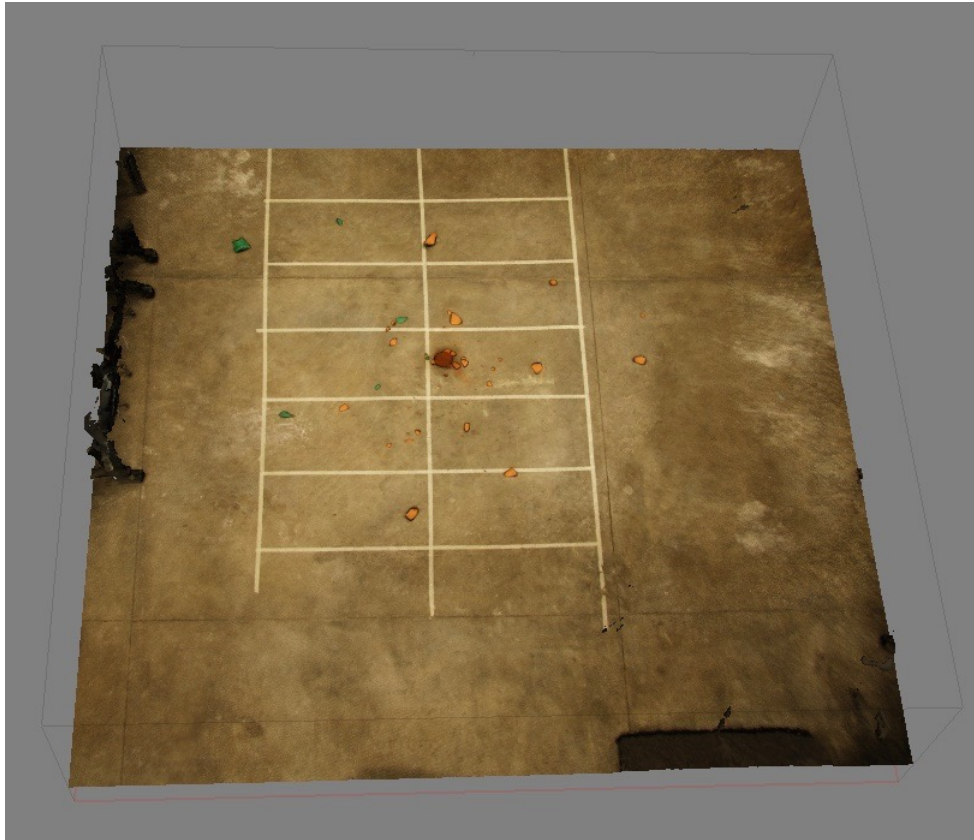


Figure 9. Finished 3D model with texture file applied.

Finally, the model and texture files were exported from the program allowing them to be viewed later in different programs. These models shown were created using a departmental PC computer and imaging software called PhotoScan. PhotoScan is used to generate 3D models through a photogrammetric process by overlaying photographs. All equipment and software was housed in the Department of Anthropology's laboratory. Within these experiments, photogrammetry aided in overall analysis of the breakages, as I was able to examine multiple trials of breakage in a three-dimensional format that allowed me to "revisit" the site of breakage. Through this program I was also able to calculate further measurements that were not taken in the field and later determined relevant to the study. In addition, images and models produced through this photogrammetric process

have been used to further illustrate otherwise confusing topics concerning formation processes and archaeological assemblages within publications and public outreach. The overall results of these experiments and documentation techniques and applications will be discussed in the next chapter as I further discuss the implementation of photogrammetry in my analysis of the breakage scenarios.

Chapter Four: Results & Discussion

In this chapter, the results of the experiment are discussed alongside the relative documentation techniques utilized in these experiments. Limitations and the extent of controlling variable are also discussed in this chapter as they deal directly with the experiment's overall results. Overall patterns of ceramic dispersals observed are discussed as well with hypotheses concerning their actual meaning or factors leading to these patterns.

Analysis & Exploration of Documentation

The general approach to documenting these experiments went along the lines that there was no such thing as "too many records." Indeed, this documentation process paid off as I found myself using the photographs, sketches, videos, and 3D models. Each documentation method had its drawbacks when it came to analyzing breakage scenes however they also possessed unique features that other documentation techniques did not have. For example, I could not entirely trust my sketches, as I was unable to correctly draw and scale the pottery assemblages in my drawings. Because of this, the sketches served as a general map of the breakage scenes illustrating specifically the locations of certain areas of the vessels (rims, base, etc.) rather than a reliable documentation of the entire scene.

Video

When it came to analyzing the experimental results, I relied heavily on the sketches, photographs, videos, and measurements taken at the scene. As stated previously, a camera was set up to record each breaking scenario in slow motion. These videos are extremely

helpful when trying to understand formation processes and were used later in my own analysis to analyze initial fragmentation of the pots and proved to be especially useful when examining the nested scenarios. Being able to slow down the breakage from real time and focus entirely on the outer vessel allowed for further understand how the inner vessel was protected and remained intact in many cases. These videos allowed for further examination regarding how the sherds interacted with each other (collision, forceful directions, dispersion of stress and energy, etc.) during the initial breakage in relation to their final resting place. For example with these videos I was able to examine how each vessel impacted the ground. In fact, by focusing on this aspect captured in the videos, I was able to recognize the variability of landing across all of the experiments and how the landings (whether leaning or perfectly straight) altered the fragmentation and ceramic dispersal. By documenting these breakage scenarios in multiple ways, the breakage scenes were preserved in multiple formats, which later were utilized in analysis concerning different aspects of the assemblages. Within the field of experimental archaeology there is relatively minimal use of recording experiments through video. This may be due in part to the undervaluation of videos and their analytical ability as they are often seen as merely documentation efforts on behalf of the researcher.

3D Models

When it came to the 3D models, the most attractive feature of this documentation method was the clear images produced. These models allowed for overall clarity concerning the range of ceramic dispersal while also saving the detailed smaller assemblages in areas of the experiment. Navigating these models on the computer,

however, proved to be difficult as the controls became slow and uncooperative leading to the overall questioning of if the technique was able to be used to its fullest potential for these experiments. Despite these inconveniences, the 3D models ended up expanding my understanding of the three-dimensional space in which the experiments were conducted. Without these models, I do not believe I would have fully understood or acknowledged the true dimensions of my experiment through photographs, videos, and drawings alone.

In a summary of the documentation techniques used in the general analysis of these experiments it was found that specific types of documentation techniques were useful for different aspects of analysis. For understanding the three-dimensional space of the experiments the 3D models held the most promise. Meanwhile, for analyzing specific elements or features of the pots, sketches were deemed the most appropriate as they were uncluttered with irrelevant data and details. For understanding the initial impact of the pots the video footage taken during every experiment was used as it allowed for a more meticulous analysis of initial breakage and damage of the vessels. Finally for understanding individual assemblages, the photographs taken after every experiment proved to be most advantageous as they included detailed aspects of individual sherds while also portraying the relative distance of dispersal of the assemblages.

Controlling Variables: Impact & Variability of Vessels

Within all research but especially experimental archaeology, there can be many caveats that threaten to derail a project. These pitfalls can be quite recognizable, however, there are others that prove to be more obscure and overlooked when planning the overall research. I myself have found myself stumbling into these holes and issues while

conducting my research and therefore have a new sense of awareness and responsibility to warn others of these tripping hazards, especially when conducting experimental archaeology. Two unaccounted variables I was unable to control, and are suspected of altering my overall results in some manner, were the landing manner of the vessels and ceramic flaws present in the pots before breakage.

These variables later became apparent when analyzing my data and undoubtedly influenced the results of the experiments. One variable I did not account for was ensuring that the pots would fall directly on their base (also known as falling flat). When examining the initial fracturing patterns of the pots as they made contact with the floor, I noticed this discrepancy across the experiments as some pots landed on their base-edges leaning forwards or sideways. After analyzing all the videos at an extremely slow speed, I realized this altered the spatial distribution of the sherds and the initial stress each pot faced when impacting the ground.

The cracks and fractures that form throughout the vessel are not unlike that of lightning. With lightning, if you are unfortunate enough to be struck by it, it will travel throughout the body as it attempts to find the fastest way to make contact with a grounded surface such as the floor. This is similar to the impact stress the pot experiences or is subjected to as it seeks to alleviate the propelling force. Impact stress can occur “when a force is applied suddenly and with momentum” such as a sharp blow (Rice 2015:360). When it comes to lightening, the electricity courses through our bodies in an attempt to find the fastest way to make contact with the ground. This is similar to the impact stress the pot experiences or is subjected to as it hits the ground. Like the lightning, the pot seeks to alleviate or dissipate the foreign force. For pots, this energy or impact stress runs

through relatively the same process as the lightning, however, these vessels are brittle and do not allow for the quick transmission of energy. As a result, the stress coursing through the pot creates fractures or cracks which “generally start at preexisting flaws or micro cracks” (Rice 2015:361).

In a way, cracks and fractures reveal these impurities or faults within the ceramic material and form. Furthermore, the stress applied to the pot is directly dependent on how the pot impacts the ground surface. For example, if a pot impacted the ground while leaning slightly, its relative ceramic dispersal will be different than another pot that landed flatly on its base. This is due in part to the amount of surface area the impact stress is able to make initial contact with. This variation must play some role in the overall dispersal of sherds as it alters the initial impact area of the pot and initial point of stress. Due to this, it is possible that these breakage experiments have been altered due to this variation on landing.

Another variable that was not account for was the structural weaknesses of some of the vessels being broken. To elaborate on this point, the vessels used in experiment 1A and 2B were found to have a black tempered interior suggesting that during the firing of the two vessels, the carbon was not completely burned off (Fig. 10). This factor could alter the structural integrity of the vessels and should be noted within the experiment. Since this flaw could not be noted or addressed until after the vessels were broken, these vessels and their breakage data was included in the analysis and final results of the experiments. Due to the time constraints, I was unable to conduct these two experiments again with other pots.



Figure 10. Reassembled base from experiment 2B illustrating the black temper found inside of the sherds VS. Reassembled base from experiment 1CD illustrating a regular temper (right).

These variables discussed above were not originally foreseen and therefore may have altered the resulting ceramic dispersals observed. If one variable, (previously unaccounted for) suddenly comes into play, other variables (previously not present in the scenario) can suddenly emerge and alter the scenario entirely. This is why researchers must plan out their experiments and research relative to the “scale of analysis that suits his or her questions” (Evans and Daly 2006:128). These decisions concerning what variables the researchers will control “can make all the difference in producing meaningful analytical output” (Evans and Daly 2006:128). I will now present the relative results of the experiments as well as some guidelines on how to conduct archaeological experiments successfully by outlining mistakes and common misconceptions.

Results

From these experiments, I can highlight some observations and relative patterns relating to the breakage of vessels and their relative heights of breakage. It should be noted that, interestingly enough, each breakage scenario produced between 25-35 sherds despite some scenarios utilizing more than one vessel.

Concerning the breakage scenarios utilizing nested pottery, I have documented four observations from which I extrapolate my conclusions. First, it was observed that nested vessels broken at chest height (Experiment 1CD and 1EF) exhibit the same impact pattern with the base of the outer vessel. This pattern appears to be a circle with the base of the vessel fragmenting into wedges (Fig. 11). Nested vessels dropped at higher heights, however, did not show this pattern, which leads me to believe it relates to the height factor of the relative drop and that the vessels are nested.

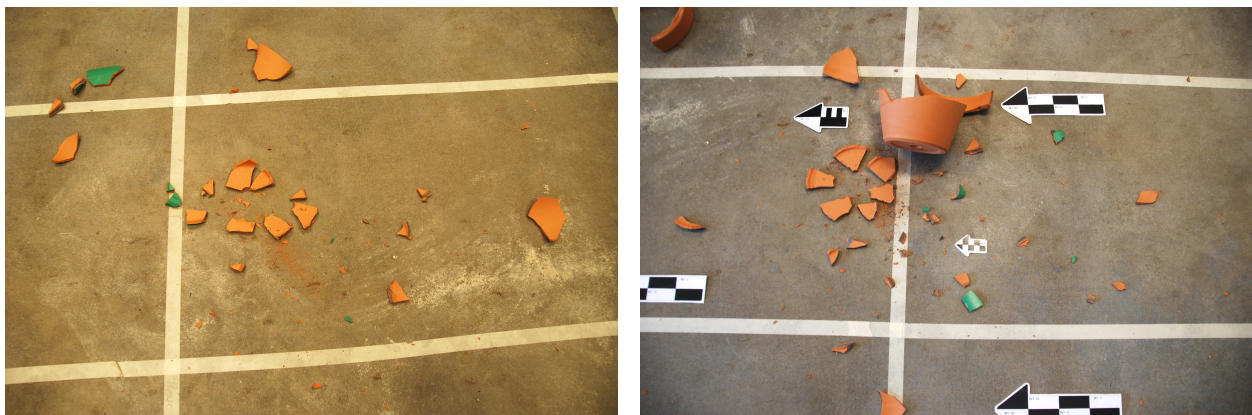


Figure 11. Experiment 1CD (left) and experiment 1EF (right) displaying the circular base pattern found in nested chest height breakage scenarios.

Second, nested vessels in these experiments were noted to have a smaller dispersal area than single vessels when broken at both heights (Fig. 12). I hypothesize that this may be due to the added number of pots in the scenarios, which contribute to overall weight and

may block after-impact fragmentation. It is shown in these experiments that nested vessels shattered producing the same amount of sherds as single vessels despite the difference in the number of pots involved in the two scenarios, however, when it comes to overall dispersal distance away from the origin, the single vessel breakages reign supreme.

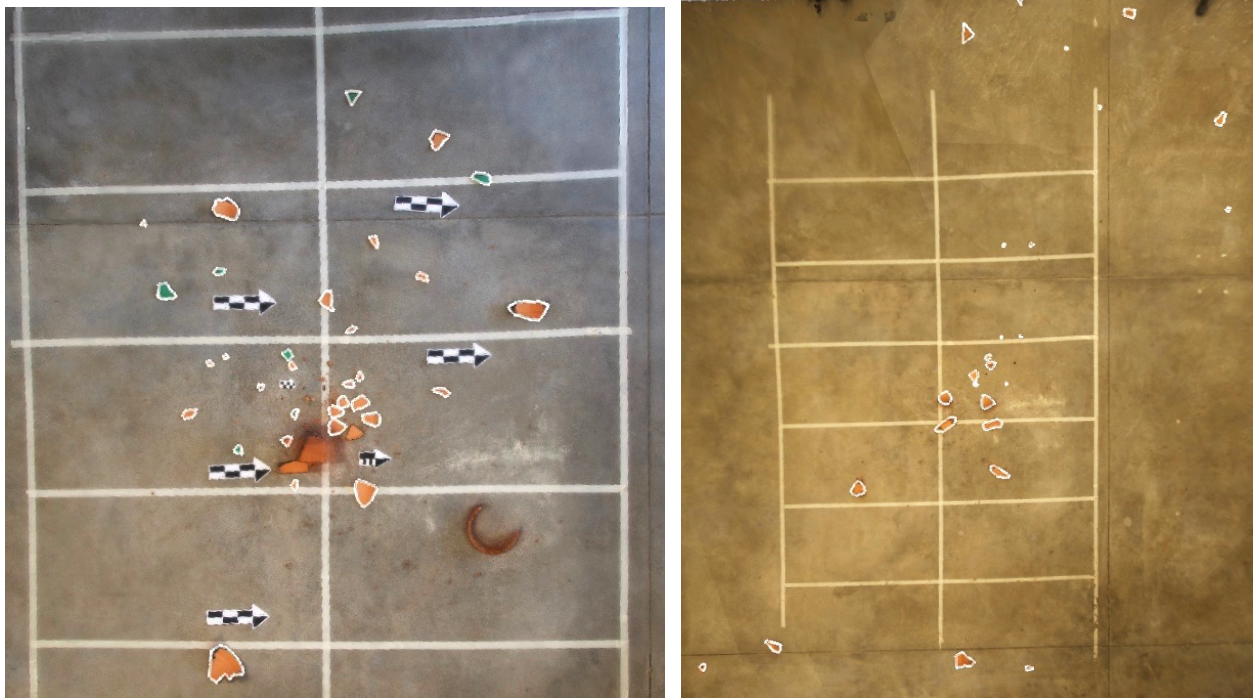


Figure 12. Experiment 1EF (left) and experiment 1A (right) illustrating an example of the relative dispersal area covered by the fragmented sherds (sherds outlined are those of the outer vessel in the case of 1EF and the singular vessel in the case of 1A).

Third, in nested breakage scenarios, it was noted that the outer vessel's rims formed the boundary of the breakage scenario. By this I mean to convey the fact that the outer vessel's rim pieces surround the entire breakage scene and are the farthest fragments from the breaking origin (Experiment 1CD and 1EF). In these experiments, the boundaries are clearly defined, however, they are less defined in experiment 1EF (Fig. 13).

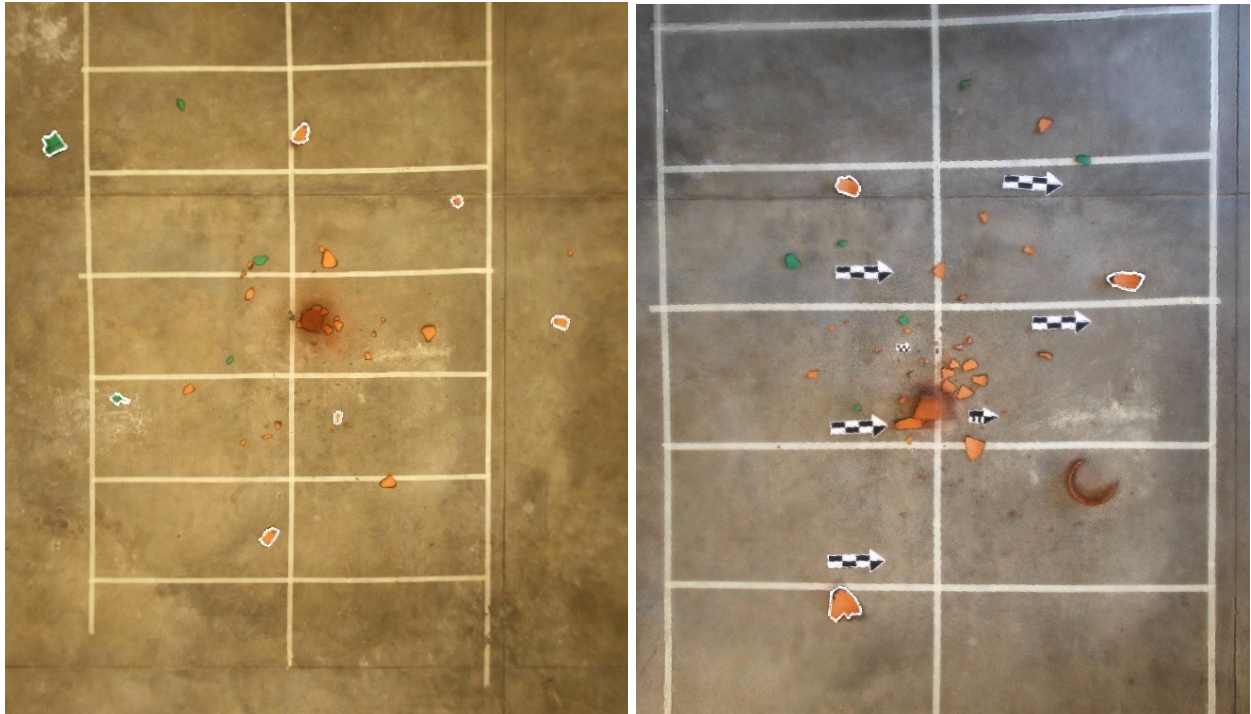


Figure 13. Experiment 1CD (left) and experiment 1EF (right) in which the outer vessel's rim pieces are outlined in white.

I attribute this to the manner in which the nested vessels fell as they landed tilting forward slightly. In the experiments in which the inner vessel was damaged upon impact (such as experiment 1EF), the inner vessel's rim pieces were found to be close to the impact zone (Fig. 14). Fourth and finally, nested vessels dropped from head height appeared to land on their relative corners of their base. I attribute this trend to the added weight of the inner vessel and the possibility that it somehow adds some rotational factor in the falling process.



Figure 14. Experiment 1EF in which the inner vessel's rim pieces are outlined in white.

When it came to single vessel breakage scenarios, two patterns were observed and documented. First, single vessels dropped from all heights were found to produce an area where no sherds were dispersed or landed (Experiments 1A, 1B, 2A, and 2B). This area seems to have some connection with the initial impact area of the vessel in regards to which part of the base impacted the ground first (Fig. 15). It is noted that this clear area void of sherds appears directly across from the initial point of contact. As previously stated in the discussion concerning nested vessels and relative dispersal distance, it was observed that single vessels have a larger fragment dispersal range than nested vessels, which serves as the second pattern observed amongst single vessel breakages.

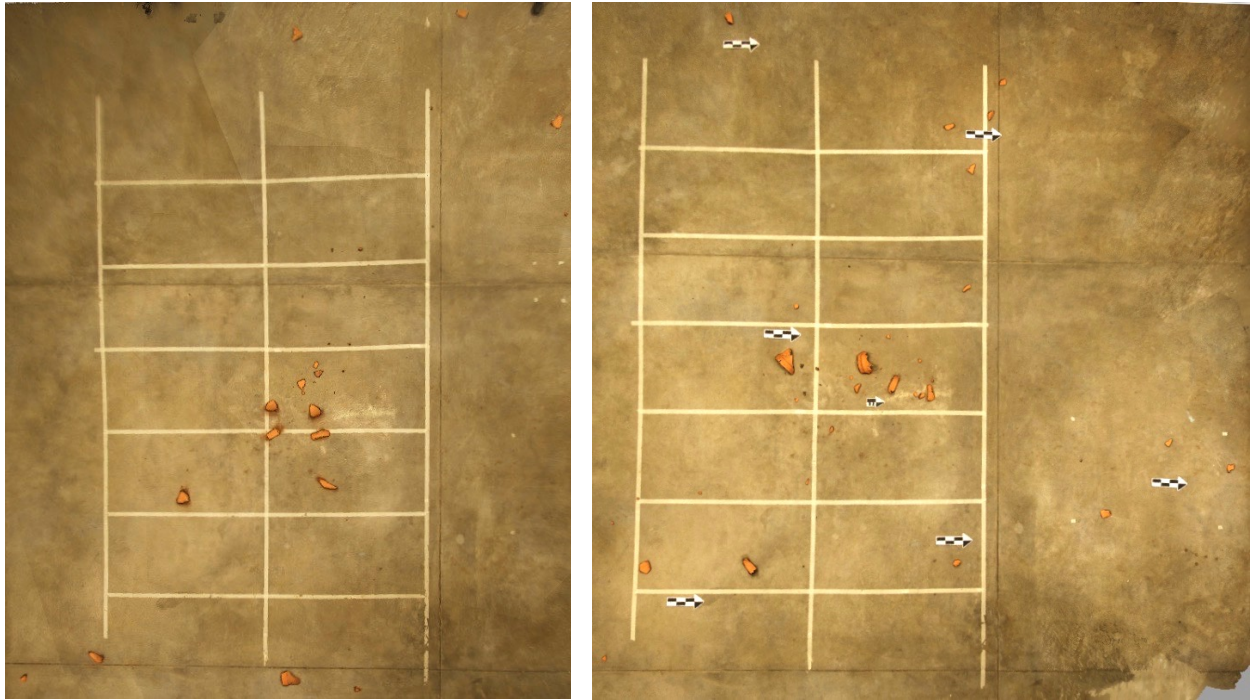


Figure 15. Experiment 1A (left) dropped from chest height and experiment 2B (right) dropped from head height.

My ability to analyze these breakage scenes and recognize these patterns of dispersal was made possible by the utilization of photogrammetry and the subsequent production of 3D models. Through these models, I was able to manipulate the breakage scene allowing for further examination of clusters or assemblages of sherd fragmentations relative to their final landing location. With this documentation and modeling technique, I was able to record the entire breakage scene while preserving the more detailed aspects of the pottery and its fragmentation. Amongst other documentation techniques, these two aspects are hardly ever preserved in tandem with one another as one is often sacrificed for the other.

Furthermore, these models allowed for additional measurements to be calculated in the case that the records had been misplaced or never documented at all. These models also

enabled me to cross analyze breakage experiments as I attempted to establish similarities between scenarios and formulate breakage patterns. Indeed, the measurements calculated through the program proved to be quite telling in respects to overall dispersal patterns and commonalities across breakage scenarios. I found that by creating and utilizing these breakage models, I was able to experience and truly retain my understanding of the ceramic dispersal and three-dimensionality of the breakages. The program also allowed for the creation of polygons. In this aspect, I was able to draw on the 3D model and outline certain sherds (as seen in figures provided above with white outlined sherds). This proved to be extremely useful as I was able to categorize certain groups pertaining to the specifications I set. For example, I was able to create a layer of shapes that outlines the sherds that were rim fragmentations (Fig. 16). These shapes had the ability to be named and labeled in such a manner that I was able to easily differentiate them from each other. This aspect of the program allowed for a more simplistic viewing of the overall dispersal patterns whereas before I was consulting numerous sketches and charts to determine this information. Furthermore, these shapes or outlines could be turned off or on when viewing the 3D model allowing for quick comparisons of created groups.

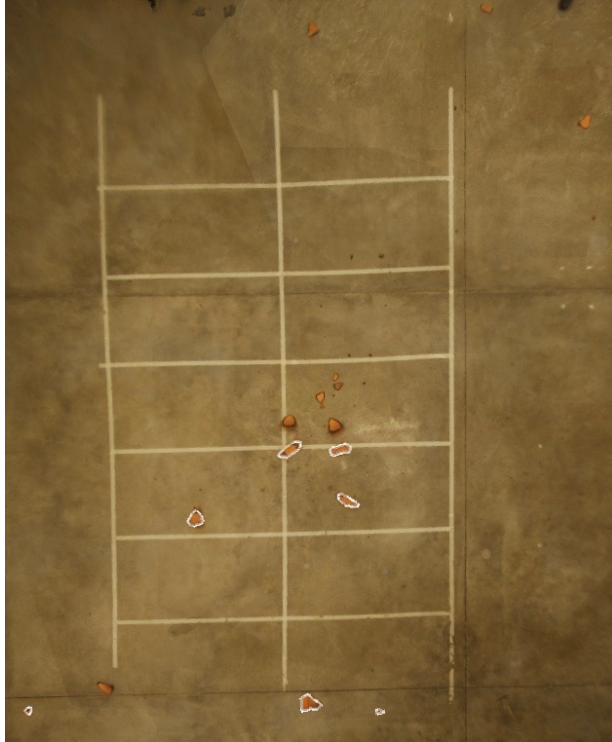


Figure 16. Experiment 1A 3D model in which the rim pieces of the pot are defined and outlined in white.

This documentary technique, unlike more traditional methods such as sketches, videos, and photographs, ensures real world perspectives as it preserves the dimensionality within and understanding of an archaeological site, which is often forgotten or overlooked initially. Furthermore, it simplifies a breakage scene and allows for a clearer understanding concerning dispersal patterns and overall formation process of an assemblage. I believe that photogrammetry not only serves as a reliable and contemporary documentation method, but also as a technology that, when applied correctly, has the ability to be utilized in imperative aspects of analysis.

Chapter Five: Conclusions

In this final chapter, I discuss the overall advantages of experimental archaeology and the utilization of photogrammetry in documenting and analyzing these experiments. Integrating technology into archaeology will also be addressed followed by some ideas for future research modifications and improvements.

Advantages of Experimental Archaeology

With experimental archaeology there is the opportunity to produce “showable” results utilized in other “hard science” disciplines. Rather than relying heavily upon interpretation, experimental archaeology produces and falls back upon the experimental process and results produced. Through this process, archaeologists are able to produce data sets and computer modulations, which are not often seen in publications or reports within the discipline.

Experimental archaeology is extremely advantageous for expanding co-collaboration across multiple disciplines. When conducting experiments, archaeologists may call upon a specialist in another field unrelated to their own such as ceramics, geology, engineering, forgery, and more. These contributions from other relative fields could help expand ideas and could lend access to reliable and accurate results through experimentation. This form of research provides the opportunity for archaeology and other disciplines to interact, collaborate, and establish new ideas for research, thereby keeping archaeology relevant in the public mind.

I speculate that the lack of experimental studies relates in some way or another to the general acceptance of experimentation within the archaeological community. Unlike

other specializations within the field such as ceramic research or landscape studies, experimental studies are not considered a definitive section or category of archaeology in which people identify with. This could be due to the many ways experimental research can be applied across the discipline lending itself to many different aspects of research. I feel that I should also mention publications as I discuss experimentation and its general acceptance in the field. Unlike more uniform or traditional studies, experimental archaeology allows for an uncommon format of conveying ideas and theories. In a way experimental research is experimental in both nature as well as overall presentation.

Experimental studies offer archaeologists an opportunity to take a step outside of the somewhat strict publication format and advocates for an entirely new formatting system altogether (possibly one with a more personal voice). Despite this refreshingly new format, modern day publications call for research to be uniform in nature and design emulating that of the scientific method. This in a sense is causing experimental studies to lose some of their explorative value as they alter themselves to fit modern day publication formats in order to reach an audience. In the future, I hope publications and writing styles concerning experimental archaeology will evolve to become less restricted in design and format as it takes away from the exciting new approaches being taken to study archaeology.

Integrating Technology into Archaeology

Archaeology, like other disciplines, must stay relevant in order to survive. With technology integrating itself into nearly every aspect of our day-to-day lives, archaeology has the opportunity to stay relevant in the public forum by implementing new

technological capabilities and techniques. Experimental archaeology serves as the platform to assess, evaluate, and challenge these new technologies and their perceived capabilities in an archaeological context. By integrating the study of the past, the technology of the present, and preparing for technology and techniques of the future, archaeology will be able to continue to contribute to our greater understanding of the past, as new technologies allow us to view sites and points of view in different formats (e.g., three-dimensions, birds-eye view, real-time, etc.). This experimental aspect also allows archaeology to become more accessible via new technologies and interactive platforms enabling archaeologists to share and update the public on the discipline itself.

Future Steps

For future experimentation concerning the concept of accidental breakage, a few adjustments should be added. First, it would be beneficial to mark the outer vessel in multiple colors rather than one. Originally this coloring method was used in order to differentiate the inner and outer vessel; however, the issue of the matter became determining where the sherd originated from within the vessel. This issue became apparent when analyzing the resulting spatial distribution of sherds, as I suddenly found myself unable to trace the true paths of the rim, base, or body sherds from the initial point of impact of the entire vessel. In order to examine this factor of dispersal I would have been required to repair the fragmented vessels and reexamine the 3D models again. In order to avoid this tedious task in the future, I advocate for a spectrum of colors to be applied to the pots, as it would help the researcher trace the original location of each sherd relative to its color.

Second, I would design a way to ensure the pots impacted the floor in the same manner. By this I mean the tipping and leaning of the vessels as they fell from relative heights. Since these pots impacted the floor at various angles, the directionality of the force or stress placed upon the pots varied across all breakage scenarios. This directly impacts the dispersal pattern, not to mention overall degree of fragmentation of the vessel itself. In the future it would be advantageous to design a method to ensure that all the vessels impact the floor in a similar manner. One way this could be ensured would be by placing a wooden rod through the vessels (as they have hole in their center), which could guide the vessel evenly to the ground. These changes should be made in the future before any attempt to study the difference between accidental and purposeful breakage is attempted.

I believe that a perfect conclusion not only outlines future thoughts concerning research but also a warmhearted reminder concerning topics discussed. “An honest appraisal of experimental archaeology can go as far as, but no further than [this]: where history is silent and the monuments do not speak for themselves, demonstrations cannot be expected... the utmost is conjecture supported by probability” (Wise 1742:5).

Experimental archaeology has the power to “provide or deny” conjecture concerning past human activities and therefore remains a critical aspect of modern archaeology today (Coles 1979:48).

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